

tion region 19. Thus, a separation of compounds is achieved that is based on the components present in a mixture being separated in elution volume by the LC column and different elution volumes being deposited in different space on the moving belt and being transported into the ionization region 19 after removal of the solvent so that separated compounds are vaporized and ionized at different times. The use of a hot gas stream to vaporize compounds has the advantage that compounds are heated at the surface rather than beneath the surface as in resistive heating. The heated gas sweeps molecules from the surface as they attain sufficient energy to escape the forces that bind them to the surface. This is a more gentle method for releasing compounds from a surface and occurs at a lower temperature than required to vaporize the molecules using resistive heating. Therefore, thermal fragmentation is reduced. Compounds ionized with these methods will have all of the analytical benefits of the mass spectrometer being employed as to generation of fragmentation and making accurate mass measurements.

[0054] FIGS. 1 and 2 show an embodiment of the invention in which an enclosure 11 is attached to a mass spectrometer 50 with an entrance aperture, or nozzle, 54 for introducing ions into the vacuum region of the mass spectrometer 50. The enclosure 11 has an arrangement for generating a gaseous discharge by applying a high voltage (typically from 1000 to 10,000 volts, preferably from 2000 to 6000 volts) to a metal needle electrode 36. A counter electrode may also be present and is typically at ground potential. The ionization region of enclosure 11 has an inlet for optional introduction of gases 66 or liquids 67 through inlet 27 of probe 28. The enclosure 11 also has a gas outlet 39 through which the gases are allowed to quickly exit the enclosed region. The gas outlet is frequently connected to a chemical hood but is normally closed when using the ATD device to force the heated gas to exit through opening 26 to aid in removing solvent from the ATD moving belt. Most of the gas exiting the source enclosure through 26 is typically swept to a vented hood device through exit 13. FIG. 1 shows a probe 28 with a connector inlet 27 for connecting an LC column or liquid/gas infusion syringe so that a liquid or gas can enter the ionization region 19. The LC column can be connected through line 14 to either the ATD device 40 as shown in FIG. 1 or to the connector inlet 27 to the ESI or APCI probe 28. The probe 28 has an internal heater 33 for heating a gas, typically nitrogen introduced through inlet 29 that is used to vaporize compounds from the ATD transport wire, ribbon, or belt 23. The wire, ribbon or belt of the ATD device 40 enters and exits the ion source enclosure 11 through apertures 17 and 15, respectively, and through the flange opening 26. Rollers such as 16 and 22 direct the wire, ribbon, or belt 23 to the ionization region 19 and directly under probe 28 that supplies heated gas 29A for vaporizing analyte. Two adjacent electrically insulated from the ATD rollers 18 can be used to apply an electric current through connection 15 to a metal wire, ribbon or belt outside the ionization enclosure 11 to heat that section between the rollers to remove any residual sample to prevent carryover. As shown, the vaporized residual sample exits through 13. Alternatively, a spool can supply the heat resistant material for the ATD for one time use. The material may be thread, string, wire, or ribbon. The discharge needle electrode 36 is typically located within 5 centimeters, and preferably within 2 cm of aperture 54.

[0055] FIGS. 1 and 2 further show an embodiment of the invention in which the ionization region enclosure 11 contains an entrance aperture, or nozzle, 54 for introduction of

ions into the mass spectrometer vacuum region 53, a metal or metal coated needle-shaped electrode 36 for application of a high voltage to generate an electric discharge, or alternatively, 36 can be a nanospray capillary containing a solvent for ESI, a gas outlet, or vent, 39, and a gas inlet 29 through 28 for introducing a gas. The source enclosure 11 has a port, or opening, 55 for an LC interface probe 28 and a port 30 for receiving the ATD assembly 40. When the ATD 40 is fitted to the enclosure 11, the gas exit 39 is blocked or partially blocked to force a higher flow of heated gas 29A from the ESI, APCI, or specially made device to exit through the flange opening 26 and out through port 13.

[0056] FIG. 3a shows an example of results observed by plotting the protonated molecular ion signal obtained from application of 1 microliter of 1 part per million solutions (1 nanogram) of beta-carotene applied sequentially to the moving metal ribbon of the ATD. The samples are vaporized and ionized using the ATD device 40 for rapid sample introduction. FIG. 3b is the mass spectrum obtained from one of the sample spots as it moves through the ionization region 19. The ion observed at m/z 537.45 is the protonated molecular ion of beta-carotene, a compound that is poorly ionized by either ESI or APCI requiring several times more sample to achieve comparable results. The ion at 553.44 is oxidized beta-carotene.

[0057] Those skilled in the art, having the benefit of the teachings of the present invention as hereinabove set forth may effect modifications thereto. Such modifications are to be construed as lying within the contemplation of the present invention, as defined by the appended claims.

Figures

[0058] FIG. 1: Sectional side view cutout drawing of atmospheric pressure ion (API) source showing the ATD (40) and the LC interface probe (28) (ESI or APCI).

[0059] FIG. 2: Sectional top view cutout drawing of the ATD (40) and the atmospheric pressure ion source for a mass spectrometer.

[0060] FIG. 3: (a) Base peak chromatogram of five injections of beta-carotene using the ATD interface to transfer sample into the atmospheric pressure ionization region. (b) Mass spectra of beta-carotene obtained from one injection. Injections made approximately every 10 seconds.

What is claimed is:

1. An ionization source useful for ionizing analyte at, or near, atmospheric pressure by ionizing the vapors induced by application of heat to analyte introduced directly into the ionization region from exterior of the ion region enclosure by application of the analyte in solution to a moving wire, ribbon, or belt of an analyte transport device (ATD) that transports analyte from exterior to the interior of the ion region enclosure and introducing the ions produced from the said vapors into the vacuum region of a mass spectrometer for mass analysis of the ions, the source comprising:

an ionization arrangement,

an enclosure for enclosing the ionization arrangement thereby defining an ionization region, the enclosure having at least one port for introducing a liquid effluent and an additional port for the ATD used for inserting samples into the ionization region and an aperture for introducing ions into the vacuum region of the mass spectrometer,

a port for introducing a heated gas to assist in vaporizing the analyte introduced by the ATD, the port may be the same or different from the port used for introduction of